DOCUMENT 462-10

OPTICAL SYSTEMS GROUP

MULTIMEDIA ARCHIVING: VIDEOTAPE, COMPACT DISC (CD), DIGITAL VERSATILE DISC (DVD), AND BLU-RAY DISC (BD) MEDIA

WHITE SANDS MISSILE RANGE
REAGAN TEST SITE
YUMA PROVING GROUND
DUGWAY PROVING GROUND
ABERDEEN TEST CENTER
ELECTRONIC PROVING GROUND
HIGH ENERGY LASER SYSTEMS TEST FACILITY

NAVAL AIR WARFARE CENTER WEAPONS DIVISION, PT. MUGU
NAVAL AIR WARFARE CENTER WEAPONS DIVISION, CHINA LAKE
NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION, PATUXENT RIVER
NAVAL UNDERSEA WARFARE CENTER DIVISION, NEWPORT
PACIFIC MISSILE RANGE FACILITY
NAVAL UNDERSEA WARFARE CENTER DIVISION, KEYPORT

30TH SPACE WING
45TH SPACE WING
AIR FORCE FLIGHT TEST CENTER
AIR ARMAMENT CENTER
ARNOLD ENGINEERING DEVELOPMENT CENTER
BARRY M. GOLDWATER RANGE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **FEB 2010**	2. REPORT TYPE	3. DATES COVERED **00-10-2007 to 00-11-2009**
4. TITLE AND SUBTITLE **Multimedia Archiving: Videotape, Compact Disc, and Digital Verstile Disc Media**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER **OS-030** 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Range Commanders Council,1510 Headquarters Avenue,White Sands Missile Range,NM,88002**		8. PERFORMING ORGANIZATION REPORT NUMBER **462-10**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Provides a short background of videotape, CD, DVD, and Blu-ray; the characteristics and life expectancy of each; and how to archive information using proper storage and handling techniques.

15. SUBJECT TERMS
Optical Systems Group; media depository;

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**42**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

This page intentionally left blank.

DOCUMENT 462-10

MULTIMEDIA ARCHIVING: VIDEOTAPE, COMPACT DISC (CD), DIGITAL VERSATILE DISC (DVD), AND BLUE-RAY DISC (BD) MEDIA

FEBRUARY 2010

Prepared by

OPTICAL SYSTEMS GROUP

Published by

Secretariat
Range Commanders Council
U.S. Army White Sands Missile Range
New Mexico 88002-5110

This page intentionally left blank.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

PREFACE

As organizations accumulate and store large amounts of visual information, there is a need to continually search for more reliable and cost effective ways to archive the information. The original report, published in 2004, explored three of the most prevalently used methods for archiving; they were videotape, compact disc (CD), and digital videodisc (DVD). The DVD acronym is also used interchangeably to identify digital versatile disc. The goal of the report was to provide the reader with a short background of the three recording mediums, the characteristics and life expectancy of each, and how to archive information using proper storage and handling techniques. The 2004 report was prepared by members of the Optical Systems Group (OSG) Photo Lab Working Committee from the Eglin Air Force Base (AFB) Multimedia Center. Contributors include Dennis Spotts, Candice Nash, Louis Hebert, and Shirley Howell. Editing was by Marvin Cochrane.

This 2010 update to the report incorporates a fourth storage medium, the Blu-ray disc. The characteristics and capabilities of the Blu-ray technology are addressed in Chapter 3. The OSG membership notes the high technical quality of Chapter 3 and expresses gratitude to Mr. Steve Csaszar, Air Armament Center (AAC), for its completion.

Please direct any questions to:

Secretariat, Range Commanders Council (RCC)
ATTN: TEDT-WS-RCC
100 Headquarters Avenue
White Sands Missile Range, New Mexico 88002-5110
Telephone: (575) 678-1107, DSN 258-1107
Email: wsmrrcc@conus.army.mil

This page intentionally left blank.

ACRONYMS AND INITIALISMS

AFB	Air Force Base
ANSI	American National Standards Institute
BD	Blu-ray Disc
BDA	Blu-ray Disc Association
BD-R	Blu-ray Disc (recordable).- for PC data storage
BD-RE	Blu-ray Disc (rewritable).- for HDTV recording
BD-ROM	Blu-ray Disc (read-only). - for pre-recorded content
BD-RW	Blu-ray Disc (rewritable).- for PC data storage
CD	compact disc
CD-I	compact disc-interactive disc
CD-R	compact disc-write-once standard
CD-ROM	compact disc-read only memory
CD-ROM/XA	compact disc-read-only memory/extended architecture
CD-RW	compact disc-rewritable
CD-V	compact disc-video disc
DVC	digital video cassette
DVCPRO	DVC-Professional
DVD	digital versatile disc; digital video disc
DVD-RAM	DVD-Random Access Memory
DVD-ROM	DVD-Read Only Memory
EMD	Eglin Media Depository
ENG	Electronic News Gathering
g/m^3	grams per meter cubed
GB	gigabyte (1,073,741,824 bytes or 1,024 MB)
HD	high-definition
HDTV	HD television
HP	Hewlitt-Packard
IDE	integrated drive electronics
IPI	Image Permanence Institute
ISO	International Organization for Standardization
kPa	kilopascal
MB	megabyte (1,048,576 bytes)
mm	millimeter
MMCD	multimedia CD
NARA	National Archives and Records Administration
NASA	National Aeronautics and Space Administration
nm	nanometer
NTSC	National Television System Committee
OSG	Optical Systems Group
PAL	phase alternation line
PC	personal computer
PET	polyethylene teraphthalate
RAM	random access memory
RH	relative humidity

SATA	serial advanced technology attachment
SD	super disc
SECAM	sequential color and memory
SMPTE	Society of Motion Picture and Television Engineers
SP	Superior Performance (Betacam SP)
S-VHS	Super VHS
TBC	time base corrector
UDF	universal disc format
UV	ultraviolet
VHS	video home system
WORM	write once read many

CHAPTER 1

VIDEOTAPE ARCHIVING

1.1 Suitability of Videotape

Videotape has been used for archiving and preservation since Ampex Corporation introduced professional recording videotape in 1952. The videotape featured an expensive, two inch, open-reel format that was used selectively and was often erased and reused. As the technology improved and prices fell, videotape soon became a popular medium for archiving. But videotape was not engineered to be a permanent record, and no professional society recognizes it as a permanent recording medium today. Prolonging the life of videotape is a complex task that depends on numerous variables, some of which are beyond the archivist's control.

Figure 1-1. ½ inch open reel videotape**.**

1.1.1 Archival Requirements. Mr. William Murphy (Reference 5l) offers a definition of video preservation in his 1997 report to The Librarian of Congress, titled *Television and Video Preservation Study*. In his report, he states that "Video preservation, regardless of the image source, is an archival system that ensures the survival in perpetuity of the program content according to the highest technical standards reasonably available." The purpose of a well maintained archival system is of course the ability for the archived information to be accessed and used by those needing the information. Videotape archiving may not meet this accessibility requirement because existing videotape formats may become obsolete as new formats are developed. Examples of video tape formats are provided in Figures 1-1 through Figure 1-4.

Because technology continues to change, and because videotape will not store data forever, videotape preservation does not provide an end product. The continued preservation is a process of archival management that requires reformatting, duplication of material, and quality control standards. According to Murphy (Reference 5l),

"There are three major facets of video preservation:

a. Safeguarding the recording under secure and favorable storage conditions
b. Providing for its proper restoration and periodic transfer to modern formats before the original or next generation copy is no longer technologically supportable, and
c. Continuing protective maintenance of at least a master and a copy physically separated in storage, preferably in different geographic locations."

Also included in Murphy's report is Dr. John Van Bogart's conclusion that "Videotape possesses a special challenge to archivists, librarians, historians, and preservationists (Murphy, Reference 5l). As an information medium, videotape is not as stable as photographic film or paper. Properly cared for, film and paper can last for centuries, whereas most videotape will last only a few decades."

1.1.2 Composition of Videotape. As Murphy states, "Although the first audio tapes were acetate-based, videotape is a layered product composed of a number of elements. The underlying support of videotapes consists of a fairly durable polyester film (polyethylene teraphthalate (PET)). A back coating added to professional tapes eases transport through the tape drives and improves overall reliability. The magnetic particles - iron oxide or chromium dioxide - are contained in a polyurethane binder coated to the PET substrate. The binder is a complex compound including many different elements such as lubricants, dispersing agents, resin-type materials, plasticizers, anti-static agents, protective additives, wetting agents, polymers, and adhesives. The exact chemical compositions of the various tapes are closely guarded secrets and will vary from one manufacturer to another. Moreover, since there are no industry standards for the manufacturing of videotape the chemical composition of newly manufactured videotape is subject to change at any time." For digital videotape, introduced in 1987, the industry shifted to a metal particle tape because it could retain far more data than the oxide tape.

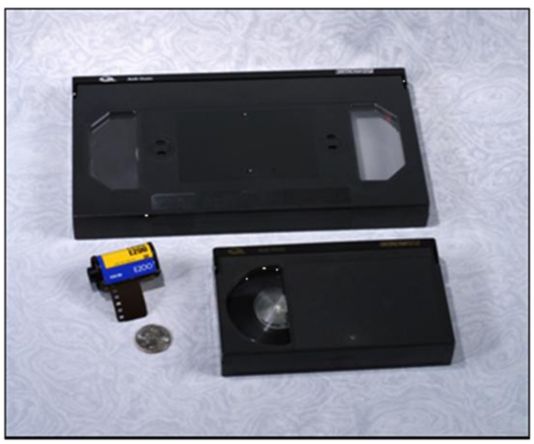


Figure 1-2. Top: VHS tape; Bottom: VHS-C

1.1.3 Deterioration and Obsolescence. Many problems videotape will prevent successful playback of program material. Some problems arise from careless handling of the videotape and by poorly maintained equipment. Many of the problems can be avoided through a vigorous training program on proper procedures to ensure videotapes are handled safely and cleanly. Over lengthy periods, however, the procedural problems mentioned above are not as damaging as the inherent deterioration and technological obsolescence of the ever-changing videotape formats and related equipment. These are concerns that make the permanent preservation of videotape a difficult and perhaps unattainable goal. However, a carefully managed plan with sufficient financial support can minimize potential losses. (Murphy, Reference 5l)

1.1.4 Longevity of the Magnetic Signal. One of the nice features of videotape is the ability of the coating particles to last many years before beginning to demagnetize. Additionally, the videotape's power to maintain its magnetic properties, called "coating coercivity," has steadily

improved with the introduction of new formats. Modern magnetic coatings, according to the 3M Company, can retain the recorded information for an indefinite period of time unless altered by erasure, re-recording, or a magnetic field. One Ampex official estimated it would take some 90 years under normal storage conditions before a metal particle videotape would lose sufficient magnetization to create noticeable degradation. Although extreme heat, such as from a fire, can demagnetize tape, magnetic performance is not an issue under proper storage conditions (Murphy, Reference 5l).

1.1.5 Chemical Stability of Videotape. From an archival standpoint, magnetic instability of the signal is not the only problem. Another problem is the physical deterioration as opposed to electronic deterioration. According to Murphy, as videotape ages, it begins to break down chemically (Murphy, Reference 5l). Eventually, it reaches a point at which the tape is no longer capable of being tracked for satisfactory playback or for transfer to another format. The primary factors affecting how and when playback becomes unsatisfactory are the length of time in storage and exposure to heat, atmospheric moisture, and pollutant gases. The earliest videotapes, lacking protective cassette housings, are the most vulnerable to damage and deterioration. Murphy describes how the destruction process occurs as follows (Murphy, Reference 5l).

> "The chemical breakdown of videotape binders due to hydrolysis has been well documented. (24) The binder's hygroscopic tendency to absorb atmospheric moisture releases acids and alcohol, products or catalysts that hasten the tape's destruction. Aged tapes are more hygroscopic than newer tapes. Elevated humidity in combination with warm temperatures accelerates the process while drier and cooler conditions slow it down. Videotapes kept in hot and humid climates have little chance of long-term survival unless placed in carefully controlled storage conditions."

1.1.6 Common Magnetic Pigments and Tape Longevity. The most commonly used magnetic pigments are iron oxide, metal particle, and evaporated metal, each of which exhibits different stability characteristics. Chromium dioxide has been used less frequently. Iron oxide and cobalt-modified iron oxide are the most stable; however, metal tapes have the ability to record a higher signal output, thereby making them desirable for improved professional performance and greater packing or concentration of data. The single homogenous metal alloy evaporated onto the substrate in 8 mm formats consists of a very thin magnetic coating that is not very durable.

> Concerning life expectancy of videotapes, a quote from Murphy is provided below:
>
> "In 1991, Sony's best estimate of longevity for these materials was about 15 years. The 3M company indicated that its research was consistent with Sony's research. The Maxell company declined to predict any life expectancy for its tape products. A TDK representative indicated he knew of no published data on tape life expectancy by his company (BASF), but that 15 years was a good guess. Evidently, manufacturers have been reluctant to provide any assurance for the extended life expectancy of videotape. Since the first metal particle pigments were unsatisfactory, several tape manufacturers collaborated in laying to rest nagging concerns about the durability of D-2, a metal particle tape that has become the principal recording format for the broadcast industry since its introduction in 1988. Tests indicated a 14-year minimum durability of the pigment before serious signal loss could occur under average conditions; basically, a

computer environment. Sony plotted much longer durability for the pigment; 24 years for one type and 96 years for another. It is important to note that these tests relate to the pigment or coating stability, and to not solve the problem of binder hydrolysis. Any tape, regardless of coating, can potentially turn into sticky "goo" in extended storage at elevated temperature and humidity. In recent years, most manufacturers have changed to more stable binders, but comparisons remain difficult if not impossible. Tape manufacturers will not divulge the composition of binders or pigments."

Mr. Jim Wheeler (see Reference 5q) stresses the idea that the environmental conditions under which videotape is stored and used are crucial to its preservation. Temperature and relative humidity play a very large role in defining proper videotape archiving. Various factors that need to be considered include light, level of cleanliness, various contaminants, and physical storage space. These factors, in addition to the physical composition of the videotape, contribute to the life expectancy of the magnetic material. The importance of a stable environment to include temperature and relative humidity levels cannot be overstated. Fluctuations in atmospheric conditions can adversely affect videotape materials by expanding and contracting, resulting in changes in their physical dimensions, which may inhibit the ability to playback the tape accurately. It is very important to monitor the environmental condition levels consistently by taking readings several times per day.

Archivists need to make a conscious decision as to the level of effort they are willing to expend to safeguard the archived material. This decision should be based on an evaluation of the benefits of storage at specific stages, the impact of format obsolescence, the projected resources to be used for reformatting copies, and an awareness of current information on modern archival techniques. Although there are many sources of information, there is probably no single source that covers all requirements for all archivists' needs. For example, film archivists can consult the Image Permanence Institute Storage Guide, but this guide only addresses preservation issues relating to film and does not address television or video. Since there is no comparable guide for video, the Optical Systems Group (OSG) researched the issue and provides the storage recommendations in Table 1-1.

TABLE 1-1. VIDEOTAPE STORAGE RECOMMENDATIONS (MURPHY)

Source	Temperature (Degrees F)	Relative Humidity
National Archives and Records Administration (NARA)	65	30%
National Institute of Standards and Technology Report	–	30-40%
SMPTE RP103 (draft version)	63 +/- 4	30% +/- 5
ANSI, IT/9, 1996 version	68 59 50	20-30% 20-40% 20-50%
AMPEX	68	30%
Peter Adelstein, IPI	50	20-30%
Note: Details of William Murphy's writings can be found at Reference 5l.		

1.2 Copying, Transferring, and Restoration

The method of recovery of data from damaged or old magnetic tapes depends upon the specific situation and condition of the tape. Before discussing the details of recovery methods, it is worthwhile to remember the causes of the damage. Damage or imperfections develop in magnetic tape primarily from inherent deficiencies such as poor layer adhesion in the early formulations, from the ravages of poor storage conditions, and from physical problems such as creases, edge damage, poor winding, and embedded dirt. Dirt is all pervasive, and as Murphy cites in Reference 5l, one video restorer observed: "There is sufficient debris on every single tape we have examined to interfere with some degree of signal retrieval." Although a certain amount of recovery is usually possible, the recovery depends upon the degree of damage. The recovery techniques, some of which are proprietary, are all designed to allow successful playback and re-recording of the damaged original. It is also noted that recovery techniques do not necessarily extend the life of the original videotape, and in fact, some techniques actually accelerate destruction.

Figure 1-3. Hi8 tape.

1.2.1 Characteristics of Restoring and Archiving. In the context of restoring and archiving, the distinguishing characteristics between copying, transferring, and restoration are shown below.

a. Copying is the straightforward dubbing or duplication of a tape, as in making a reference copy for routine use or to service another format.

b. Transferring, making a new master and reformatting, involve converting the original to an updated format.

Restoration implies an effort to make a complete and error-free copy from the best available original and minimizing all imperfections while transferring to a new copy. To provide the best possible copy, cleaning the tape beforehand is an essential part of the restoration. In theory, digital technology allows some improvement over the original through error corrections and signal enhancement. High-quality restoration is a time consuming process that drives up the cost of preservation.

1.2.2 Priority Scheme for Restoration. Murphy's guidelines for priorities in restoration are provided in the remaining portion of this paragraph (Reference 5l). Prior to restoration of archived material, the archivist must determine a priority scheme that addresses the conditions under which material is copied, restored, and maintained. A priority scheme in common use is to first restore archived material having obsolete formats and then address the remaining material. Priorities might also be determined from a physical examination of representative tapes. If loose oxide or other debris is present, cleaning the tape is necessary. This can be done with cleaning blades, burnishing points, dry paper wipes, or even by washing with water. One innovative archivist devised a 1/2 inch tape cleaner by attaching a microscreen shaver and vacuum pump to clean the recording as it played for re-recording. Another technique used in the worst

circumstances is to bake the tape at relatively low temperatures for several hours or longer. In this process, the temperature of the tape must be ramped up and down at a slow rate. This approach is used to fix loose oxide and to improve playback. None of these techniques permanently restores videotape, and tape deterioration will continue (Murphy, Reference 5l)

1.2.3 Signal Quality. Restoration of the quality of the signal recorded on the original for the purposes of improving the sound or image involves altering the information being recorded. This might not be advisable because the signal processing would tamper with the original information possibly enhancing the signal from the original material and could be a violation of a fundamental principle of archival stewardship. In cases where signal enhancement is necessary, restoration should only be conducted on copies of original materials (Wheeler, Reference 5q).

1.2.4 Time Base Correctors (TBCs). The use of TBCs can compensate for many of the video signal problems encountered when transferring or reformatting tapes. Unfortunately, some of the earliest open-reel tapes had nonstandard signals and TBCs will not provide much assistance. In such cases, copying from the earliest generation will be extremely important. Some of the formats for analog and digital videotapes are shown in Table 1-2 and Table 1-3 respectively.

TABLE 1-2. SELECTED ANALOG VIDEOTAPE FORMATS (MURPHY)

Format	Coating	Thickness	Width	Major Market
2 inch	Iron Oxide	1.4 mil	2 inch	Broadcasters, Studios
1/2 inch open reel	Iron Oxide		1/2 inch	Independent production
1 inch type A	Iron Oxide		1 inch	Government, Studios
3/4-Umatic	Cobalt-modified Iron Oxide	1.1 mil	3/4 inch	ENG, Independent production
3/4-Umatic SP	Cobalt-modified Iron Oxide	1.5 mil	3/4 inch	ENG, Independent production
Betamax			1/2 inch	Consumer
Betacam	Cobalt-modified Iron Oxide, Chromium Dioxide	0.8 mil	1/2 inch	ENG, Independent production, Government
Betacam SP	Metal particle	0.55 mil	1/2 inch	ENG, Independent production
M-II	Metal particle	0.55 mil	1/2 inch	ENG, Broadcasting
1 inch Type C	Cobalt-modified Oxide	1.1 mil	1 inch	Broadcasting, Studios
8 mm, HI 8	Metal particle, Evaporated Metal	0.8 mil	8 mm	ENG, Independent production
VHS	Cobalt-modified Iron Oxide, Chromium Dioxide	0.8 mil	1/2 inch	Consultants, Government
S-VHS	Cobalt-modified Oxide	0.8 mil	1/2 inch	ENG, Independent production

Note 1. Details of William Murphy's writings can be found at Reference 5l.
Note 2. In addition to the National Television System Committee (NTSC) versions, there are phase alternation line (PAL) and Sequential Color and Memory (SECAM) versions, although these are less likely to be found in archives. The above formats are the ones of greatest archival concern, and are those that were the most popular from 1956 to 1996 in broadcasting, industry/education, government, and the consumer markets.

TABLE 1-3. DIGITAL VIDEOTAPE FORMATS (MURPHY)					
Format	**Signal**	**Coating**	**Thickness**	**Width**	**Major Users**
D-1	Component (Sony)	Iron Oxide	0.5-0.6 mil	3/4 inch	Studios
D-2	Composite	Metal particle	0.5 mil	3/4 inch	Studios, Broadcasting
D-3	Composite	Metal particle	0.4-0.55 mil	1/2 inch	ENG, Broadcasting
D-5	Component	Metal particle	0.43 mil	1/2 inch	Studios, Production
D-6	Component	Metal particle	0.54 mil	1 inch	HDTV
DCT	Component compressed	Metal particle	0.5 mil	3/4 inch	Studios
Betacam SP	Component compressed	Metal particle	0.57 mil	1/2 inch	Broadcasting
Digital Betacam	Component compressed	Metal particle	0.54 mil	1/2 inch	ENG, Broadcasting
Digital-S D-9	Component compressed	Metal particle	0.57 mil	1/2 inch	ENG, Production, SMPTE 316M
DVCA	Component compressed	Metal particle	0.33 mil	1/4 inch	ENG, Production, Consumers
DVC/ DVCPRO	Compressed	Metal particle	0.33 mil	1/4 inch	ENG, Production, Consumers
D-7 DVCPRO 50	Compressed	Metal particle	0.33 mil	1/4 inch	SMPTE 306M
Note. Details of William Murphy’s writings can be found at Reference 5l.					

1.3 Sample Archiving Procedures: Media Depository at Eglin AFB

Practical insight into the problems of videotape archiving can be gained by reviewing the experiences of the Eglin Air Force Base (AFB) personnel who deal with the Eglin Media Depository (EMD). The EMD facility contains film, videotape, negatives, and digital images and primarily contains two types of subject matter:

a. Weapons test missions conducted at Eglin or sponsored by Eglin organizations and tested elsewhere.
b. Events of historical value that are of interest to Eglin or unique to the Air Force.

1.3.1 Eglin Multimedia Center. To organize the material for ease of access, the Multimedia Center personnel created a database that covers most of the possible facts that one might use to search for subject matter. All the known facts about an item are entered into the database during the review of each product that enters the EMD. For example, codes are entered to identify aircraft, command designation or tail number, and the activity the aircraft is engaged in. If munitions are visible, codes will specify both the type of delivery system and the target. This

computer entry of diverse characteristics will enable the depository staff to quickly identify and retrieve a product at a later time even if the customer can provide only limited information on the subject. The Eglin depository has been evolving and improving for the last fourteen years and is considered by our customers to provide efficient information retrieval.

1.3.2 Common Archival Problems. Some of the problems shown below have been encountered at the EMD and are likely to be common to other archives. The comments and problems cited below are offered as a reference for the reader who may already be involved in archiving or a reader who may be creating and operating an archival depository in the future.

Figure 1-4. Digital videotape.

a. Sufficient identification of the content is not always immediately provided with the incoming products. The depository has established a policy of not guessing. Only known facts are entered, leaving other fields blank. In addition, depository personnel ask test engineers a lot of questions and enter new facts as they are gathered.

b. Many of our customers are not familiar with our capabilities or limitations. For example, many are not aware of generation loss during reproduction and will ask the Multimedia Center personnel to edit from the third or fourth generation copy of a VHS, when the original is already on file at the EMD facility. We need to continually market our depository services because of the changing workforce of both military and civilian employees.

c. Physical storage space is very limited. Although the newer, comparatively thin digital videotapes take a fraction of the space of the old 3/4 inch U-Matic or Betacam tapes, it is necessary to inventory the archives several times a year to determine which products are no longer worth keeping.

d. As technology improves, the depository must decide which material to transfer from older 3/4 inch tape to digital format.

e. Another challenge is balancing the primary function of the EMD personnel, which is to provide materials for customers who are preparing briefings and presentations, with the other function of maintaining a historical archive. The answer lies in the eye of the beholder, and it is highly recommended that firm goals, guidelines, and priorities be established before starting an archival system.

CHAPTER 2

THE COMPACT DISC (CD) AND THE DIGITAL VERSATILE DISC (DVD)

2.1 CD/DVD Development

Throughout the last 20 years, the costs of CDs and DVDs, readers, players, and recorders have fallen significantly and in today's environment offer an excellent option for archiving data. In the 1980s, CDs became popular for audio recording and, soon after, for recording any form of digital information. Digital videodiscs (DVDs) emerged in 1995 in two competing formats; Super Disc (SD) and Multimedia CD (MMCD). Toshiba, Matsushita, Time Warner, and others backed the SD format. Sony, Philips, and others backed the MMCD Format. A group of computer companies led by IBM insisted that the factions agree on a single standard. The combined DVD format was announced in September 1995, avoiding a confusing and costly repeat of the VHS vs. Beta videotape battle or the quadraphonic sound battle of the 1970s. The DVD was later renamed the Digital Versatile Disc to indicate its ability to record multiple application formats. The evolution of the CD and DVD formats is summarized in Table 2-1.

TABLE 2-1. EVOLUTION OF THE CD AND DVD FORMATS

Date	Event
1979	Philips developed the first working prototype of the compact disc. Philips worked with Sony to establish a maximum time, frequency, and audio encoding. The 74-minute maximum time was chosen for several reasons, including conductor Herbert Von Karajan's request to accommodate his favorite piece: Beethoven's Ninth Symphony, about 74 minutes long.
1983	Sony released the first compact disc player, retailing for $1,000. 30,000 players and 80,000 discs were sold in the United States.
1984	Compact disc players improved, and portable players were introduced. The first CD pressing plant in the United States opened at Terre Haute, Indiana.
1985	Sony and Philips released the first CD-ROM (compact disc — read only memory) for computers. The audio CD player was upgraded to its third generation.
1986	The CD-I concept was introduced. The CD-I was an interactive disc to be used for storing data, text, audio, and visual information all at the same time.
1987	CD-ROM capacity was upgraded to 650 megabytes. The CD-V and CD-3 concepts were introduced. The CD-V videodisc held five minutes of analog video and audio or 20 minutes of audio. The CD-3 was an 8-cm disc that held 20 minutes of audio.
1988	The CD-R write-once standard was introduced and the development of an erasable and recordable CD was announced.
1991	The CD-I format was launched.
1995	Combined DVD format announced, establishing a standard DVD-ROM format.
1996	CD-ROMs reached the 12x speed (a 60-minute CD can be written in five minutes). CD-R was introduced with drives costing under $500, allowing users to write 650MB of data on a compact disc
1997	CD-RW (compact disc - rewritable) discs were introduced, allowing users to eraseband write a CD multiple times. The DVD-ROM was introduced.
1998	DVD capacity increased with the introduction of dual-layer discs. DVD-RAM (DVD random access memory) drives were introduced, allowing users to write their own 2.6 GB DVDs.
2002	The DVD format continues to evolve. Many experts predict that the next big thing in consumer electronics will be the digital versatile disc (DVD) recorder. Their standard format provides up to 4.7 GB of data storage, capable of holding more than two hours of high-quality video. Double-sided discs have a capacity of 9.4 GB.

2.2 CD and DVD Characteristics

The following paragraphs provide background information on the characteristics of CDs and DVDs.

2.2.1 CD Data Coding. Although the compact disc is small and wafer thin, its composition is complex and detailed. The readable surface is made up of areas called "lands" and "pits" (see Figure 2-1). The lands and pits differ in the way they reflect or diffuse light. The areas that reflect light are known as lands, and the areas that diffuse or diffract the light are known as pits. In the disc drive, a laser directs light at a rotating disc.

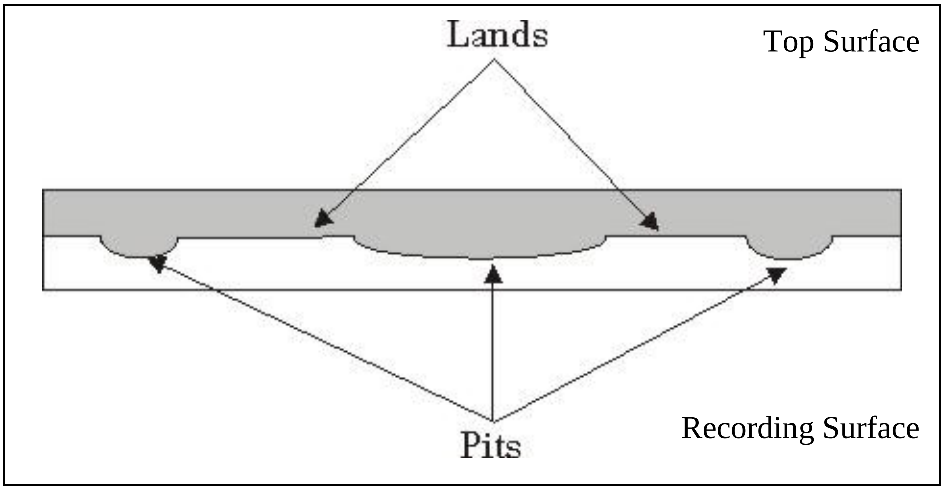


Figure 2-1. Compact disc surface.

When light hits a land, it is reflected straight back towards the sensor. When light hits a pit, it is scattered, reducing the intensity of the light that reaches the sensor. Variations in the intensity of the reflected light are converted into digital signals that the disc drive sends to the computer.

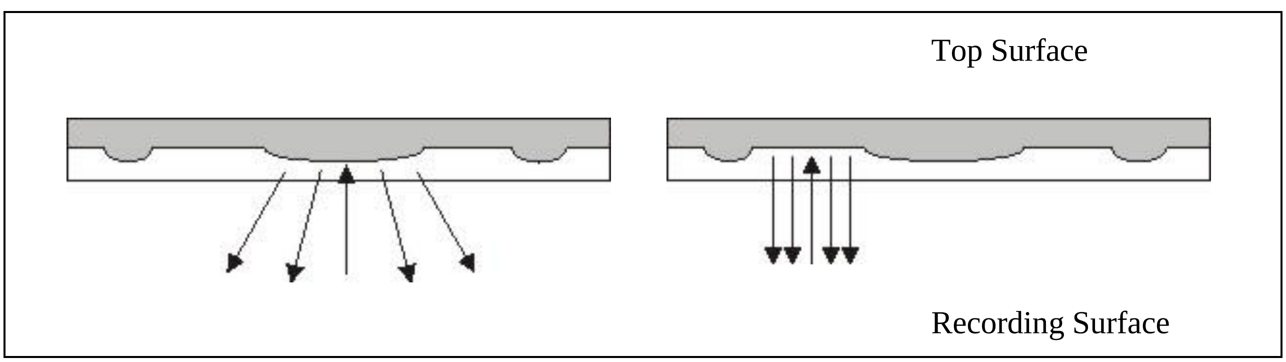


Figure 2-2. Pits (left) scatter reflected light; lands (right) reflect directly back to the sensor.

2.2.2 DVD Data Coding. Pre-recorded DVDs can hold 4.7 gigabytes of data, enough for over two hours of high-quality video with sound. This is roughly six times the capacity of CDs, which can hold up to 780 megabytes. The high recording density of DVDs is achieved by using smaller pits that are more closely spaced than those in CDs. To read this much more compressed data, DVDs must be manufactured to more precise tolerances than CDs. That is why DVD

readers use a shorter-wavelength laser beam (see information from Pioneer (Reference 5n) and Phillips (Reference 5m).

2.3 Disc Composition

With a good understanding of the various formats and materials used in the construction of discs, the archivist will be better equipped to maintain the data in the archives. The following paragraphs provide background information on the composition and formats of CDs and DVDs.

2.3.1 CD Formats and Composition. The two types of optical discs most used are replicated discs and recordable discs. They are:

a. A replicated CD or CD-ROM is a CD upon which data can be stored and accessed but cannot be altered by the user.
b. A recordable disc is manufactured at an automated stamping plant. Recordable CDs are composed of three layers.

Before the two upper layers are applied to the replicated CD, metal impressions called sons or stampers are created to produce the pits on the underlying polycarbonate layer. The disc is then coated with a reflective layer of gold, silver, or silver alloy. Then the reflective layer is protected with a lacquer coating as shown in Figure 2-3.

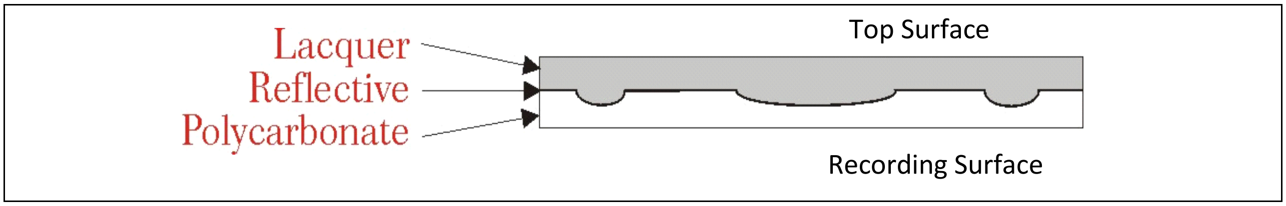


Figure 2-3. Three-layer structure of replicated discs.

A recordable CD has either four or five layers (see Figure 2-4). The label coating is not found on all CD-R disks. The polycarbonate layer of a CD-R has a sallow groove (or “pregroove”) that is used for timing and tracking in the recording process. This grooved layer is covered with a dye polymer that darkens or creates a void (creating a pseudo pit) when struck (or burned) with a recording laser beam. The reflective and lacquer layers of the recordable disc are similar to those of the replicated discs. In addition, recordable discs sometimes have a label coating, referred to by some manufacturers as the data shield. The primary benefit of this layer is that it will accept printing from inkjet printers. There are three types of label coatings: a white ceramic coating, a white semi-water soluble coating, and a resin coating.

Figure 2-4. Five-layer structure of recordable discs.

Most CDs distributed through early 1997 were replicated discs. This was primarily because there was no suitable alternative. CD-R media was relatively expensive and could not be labeled with a printer. This changed when CD-R manufacturers drastically reduced prices and introduced printable surfaces.

2.3.2 DVD Composition. The DVD specification allows for dual layer discs that requires two layers of polycarbonate substrate as shown in Figure 2-5. Single-sided discs simply record data on only one of the substrates, which is then covered with a reflective layer.

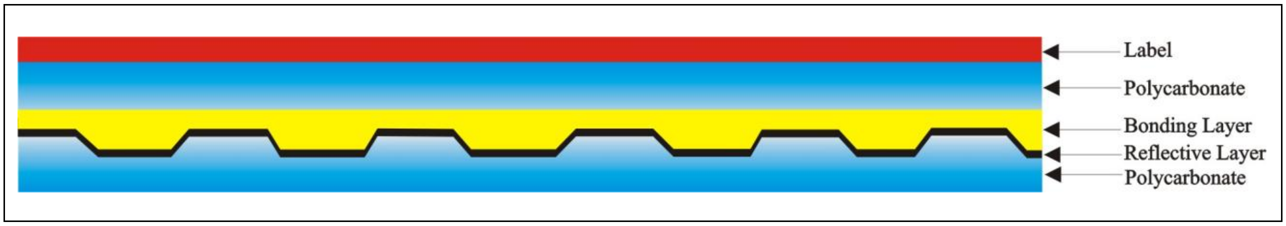


Figure 2-5. Layered structure of a single-sided DVD.

On a dual-layer disc, both substrate layers contain data and have reflective layers as shown in Figure 2-6).

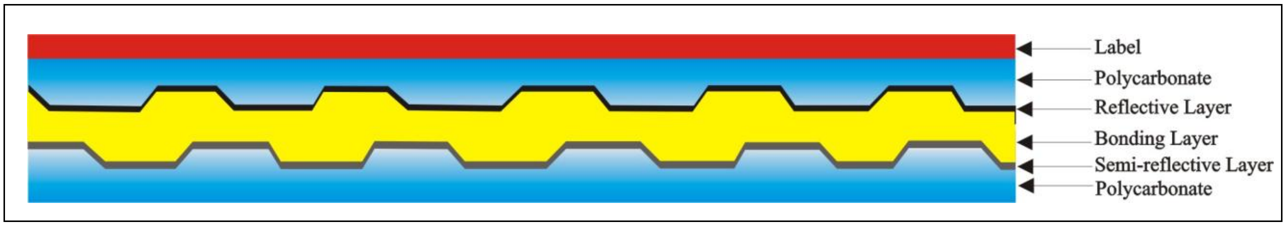


Figure 2-6. Layered structure of a double-sided DVD.

On a CD, the polycarbonate substrate layer is 1.2 mm thick. On a DVD, the two substrate layers are each 0.6 mm thick and bonded to each other by a thin bonding layer. As with CDs, the top-label side is protected by a lacquer layer. Additional information can be found from Pioneer (Reference 5n) and Disctronics (Reference 5f).

2.3.3 DVD Formats. DVDs that can be used to store data, software, or multimedia applications are available in several formats as follows:

a. DVD-ROM is a read-only format used for distribution DVDs. DVD-ROMs can be single-layer or dual layer and can be single-sided or double-sided.
b. DVD-R is a write-once format used for authoring. This is a single-layer disc with a cyanine dye layer for recording. With a 4.7 GB capacity, DVD-R provides a high-end, write-once recording media for companies that author software, movies, games, or other applications, allowing them to produce large quantities of discs with high-quality images and sound. DVD-R discs can record data to be played on most current DVD players and DVD-ROM drives.
c. Rewritable DVD formats are DVD-RAM, DVD-RW, and DVD+RW.
d. Although DVD-RAM was adopted in 1998 as the industry-standard for rewritable DVDs, the competing DVD-RW and DVD+RW formats were announced at the same time. This created confusion in the marketplace and slowed the adoption of a specific rewritable DVD standard.
e. The Rewritable DVD formats can be recorded, erased, and recorded again more than 1,000 times without any loss of quality. To achieve high-quality recording and a high level of durability, DVD-Rewritable discs use a high-performance phase change material that is ideal for mass storage and long archival life.

Format references are also shown in Table 2-2.

Many compatibility issues remain unresolved. For example, the double-sided DVD-RAM media is contained in a Type I cartridge. The media cannot be removed from the cartridge for use in DVD-ROM drives. Only single-sided DVD-RAM media, which use Type II cartridges, can be removed for use in ROM drives. Once removed from its type II cartridge, the single-sided DVD-RAM media can physically be placed in DVD-ROM drives. However, not all DVD-ROM drives are read-compatible with DVD-RAM media. Most third-generation or later DVD-ROM drives can read bare DVD-RAM media.

TABLE 2-2. DVD FORMATS

Format	DVD-ROM	DVD-R	DVD-RAM	DVD-RW	DVD+RW
Sponsor / Manufacturer	DVD Forum, Sony, Philips, ISO Standard	DVD Forum, Pioneer, Ricoh, Yamaha	DVD Forum, Toshiba, Mitsubishi, Panasonic, Hitachi	DVD Forum, Pioneer, JVC, Sharp	Philips, Sony, HP, Ricoh, Yamaha
Sides	1 or 2	1 or 2	1 or 2	1	1 or 2
Cartridge Use	NO	NO	YES / NO	NO	NO
Disc Capacity (1st Gen. Drives)	4.7 to 17.0 GB	3.95 GB (single side)	2.6 - 5.2 GB	4.7 GB	Not supported
Disc Capacity (2nd Gen. Drives)	4.7 to 17.0 GB	4.7 GB (single side)	4.7 - 9.4 GB	4.7 GB	4.7 GB (single side) *available 2001-2
Recording Medium	Molded Pits	Cyanine Dye	Phase Change	High Reflectivity Phase Change	Phase Change
Writeable	No	Yes	Yes	Yes	Yes
Rewriteable	No	No	>100,000 x	>1,000 x	>100,000 x
Other Compatibility: Read(*)	CD-Audio CD ROM /R /RW DVD-R /RW DVD-RAM (bare)	DVD-ROM	PD, CD-Audio, CD ROM /R /RW, DVD-ROM /R /RW, DVD-Video /Audio	DVD-ROM, DVD-R	CD-ROM /R /RW, DVD-ROM/R (everything but RAM)
Other Compatibility: Write (1)	None	None	PD(1)	DVD-R for General Use	CD-R/RW, DVD-R

1 Features can vary among drive manufacturers and models.

2.4 Durability

In general, the durability of CDs and DVDs is a result of the individual layers, additional coatings, the dye layers, and the stamper life expectancy.

2.4.1 CD Metallic Layer. In the metallic layer, decreased reflectivity is sometimes caused by oxidation. Oxidation is normally a slow chemical process that takes place over time. However, high humidity can cause a rapid onset of oxidation, as shown in the following examples:

a. CD Testing by Kodak has shown that silver is not stable when subjected to life testing at an accelerated pace. Silver discs from six different manufacturers were tested and all failed in less than three weeks.
b. Silver alloy and gold reflective surfaces do not oxidize. There has been some discussion that silver alloy is more desirable than gold because it has a more reflective surface. It has also been stated that the silver alloy disc requires less laser

power to write to it and less power to read, so that the CD-R lasers will last longer. However, tests have not been conducted to confirm this hypothesis.

2.4.2 The Lacquer Layer. The lacquer layer offers some protection against touching, rubbing, and very minor scratches. If the lacquer layer is damaged and the metal layer is silver, oxidation will occur rapidly. If the damage penetrates the metallic layer, total destruction of the data is imminent. The metallic layer will simply flake off, resulting in a condition commonly referred to as CD rot or DVD rot (Figure 2-7).

Figure 2-7. CD rot in upper right**.**

2.4.3 Additional Coatings. Some disc manufacturers offer an additional coating to protect the metallic layer. Currently, there are three different coatings used: a white ceramic coating, a white semi-water soluble coating, and a resin coating. Some of their characteristics are:

a. The white ceramic coating is permanent but is sometimes damaged when consumers write on it with a ballpoint pen. Even if the metallic layer is not broken through, the compression caused by the pen may damage the underlying polymer layer.
b. The white semi-water soluble coating will rub off when wet.
c. The resin coating is impervious to most solvents and acids. It is clear in color, showing the metallic layer beneath. Even though the coating is durable, the disc should only be cleaned with lukewarm plain water because the polycarbonate layer is sensitive to many chemicals. The use of any cleaning solvent, including window cleaners, will permanently damage the polycarbonate layer and make the disc totally unreadable.

2.4.4 CD-R Dye Layer. For CD-Rs, the dye layer can play a big role. These dye polymers are distinguishable by their colors. Azo is dark blue. Cyanine can be various shades of green or blue depending on the ultraviolet (UV) stabilizers that are added. The type of reflective surface used will also influence the color shades. Phthalocyanine is almost clear with a very light yellow or green tint. Some observations concerning the type of dye layers used are:

a. The cyanine-based discs have a tendency to break down when exposed to UV and become more light sensitive. Testing by Kodak and Practical Sun Light has shown that cyanine-based dye polymers have a very short to moderate life expectancy when exposed to sunlight, which contains UV radiation.
b. Azo dye polymer lasted longer in sunlight testing than did the cyanine-based dye.
c. Phthalocyanine dye, without the use of added stabilizers, has been found to be extremely stable when exposed to UV and other elements.

2.4.5 Stamper Life Expectancy. For CD-ROMs, poor quality discs can sometimes be produced when the stamper is used beyond its life expectancy. Some stamping machines have a life expectancy of only 10,000 impressions. Overuse of the stamper can account for a few CD-ROMs' inability to accept data.

2.5 Handling and Storage

Proper handling and storage are essential for preserving CDs and DVDs. Their life expectancy can run from a couple of hours to 100-plus years depending of the materials used in manufacturing and the environment. Compugraf (see Reference 5e) gives the following estimates for DVD longevity:

a. "Pressed discs (the kind that movies come on) last … anywhere from 50 to 300 years."
b. "DVD-R and DVD+R discs are expected to last anywhere from 40 to 250 years, about as long as CD-R discs."
c. "The erasable formats (DVD-RAM, DVD-RW, and DVD+RW) are expected to last from 25 to 100 years."
d. "For comparison, magnetic media (tapes and discs) lasts 10 to 30 years … "

Based on current models and calculations, 95 percent of properly recorded discs stored at the recommended dark storage condition (25 ºC, 40 percent RH) will have a lifetime of greater than 217 years.

2.5.1 Handling Guidelines. The American National Standards Institute (ANSI) offers ANSI IT9.21 (1) as guidance for how to test, store, and handle discs to prevent deterioration. The conditions that damage discs are high humidity, high temperatures over an extended time, rapid temperature changes, and exposure to light. The following recommendations will help ensure against damage from improper handling:

a. Handle only at the outer edge.
b. Do not touch the shiny (play side) surface.
c. Do not bend the disc when removing or placing in storage cases.
d. Avoid scratching, especially while placing in a player or storage case.
e. Do not expose to high temperature — avoid heat sources, hot surfaces, and direct sunlight.

Like all products, the expected durability and longevity directly correlate with the care of the discs. Cycling conditions between extremes of temperature and humidity can be very damaging. Fast changes between very warm and wet conditions to cooler and very dry conditions can produce warping and distortion.

Users are often unnecessarily concerned about magnetic fields and marking the edges of discs. Magnetic fields have no effect on CDs and DVDs. Also, coloring the edge of a disc with a colored marker will not harm the data quality, because there is a sufficient margin from the edge of the disc to the end of the data.

2.5.2 Disc Scratches. Scratches are the worst enemies of data on a disc. While most users worry about scratches on the underside of the disc, permanent damage is more likely to occur from scratches on the top, or label, side of the disc. The protective coating on the top side is a hard but thin layer. Scratches that penetrate this layer can easily damage the reflective layer and

the data layer below it. It is possible to determine if this has happened by holding the disc about 24 inches from a 40-watt light bulb, with the label side facing the bulb. If light comes through the disc, from pinholes or scratches, the disc is scratched on the label side and the scratch has penetrated the reflective layer to the data layer. The scratch is not repairable and data has been lost forever. A softer and thicker plastic layer protects the bottom, or play side, of the disc. Resurfacing and polishing out the scratches can often repair scratches on the play side. The depth of the scratch will determine the success of the repair.

2.5.3 CD Labels. Labels are particularly important. As mentioned above, ballpoint pens can wreak havoc on discs. Even if a disc has a paper label, do not write on it with a ballpoint pen. The recommended writing tool for labels is a permanent marker. Paper labels can create problems by peeling in humid conditions or flaking off and damaging the disc drive itself. Once a label is on a disc, do not try to remove it. Peeling off the label produces a lever action that concentrates stress on a small area of the disc. Also, paper labels may unbalance the disc causing the disc drive to drop to a lower speed when reading. This may cause read errors.

Labels can be printed directly on discs by three methods: thermal, inkjet, and silkscreen. Thermal printing is fairly permanent but quality is poor. Inkjet is a higher quality of printing and does not damage the disc, but it is not permanent and can smear or run when exposed to moisture. Silk screening provides high quality print, is permanent, and does not damage the disc, but it is more expensive than the other methods.

2.5.4 Storage Media. Proper storage media are essential. Cheap plastic sleeves are not suitable for long-term storage because heat and humidity may cause the disc and sleeve to stick to each other. Acrylic cases provide protection against scratches, dust, light, and rapid humidity changes. Placing the cased discs in a closed box, drawer, or cabinet can provide further protection.

Kodak does not recommend storing CD-R media long-term in soft sleeves (see Appendix-A). There are also concerns about scratching the disc when sliding it in and out and deforming the disc if it is packed in with other materials, for example, in a file cabinet. Another potential problem is the possible long-term effect of the plasticizers in some sleeve materials on the CD coatings and /or on any printing that was done.

Jewel cases and beehives are acceptable because there is no contact to the recording area of the disc. Beehives do present an access problem. Getting to disc number 22 in a beehive of 50 discs typically involves a lot of disc handling which could lead to scratching, fingerprints, and drop damage. One may consider jewel cases for frequently accessed discs, and beehives for discs that are seldom accessed. If storage space is a concern, one may consider rigid, slim line jewel cases that are half the thickness of a standard jewel case.

2.6 Affordability

When archiving multimedia items, it is actually less expensive to make and distribute a compact disc than to use two (or more) floppy diskettes. Not only is the cost lower, but also the amount of data that can be put on a compact disc is 500 times greater. For example, one scanned photo at a mid-level resolution can create an 18-megabyte file. It would take 14 diskettes to hold

that one file, but you could put that file and 35 more on one compact disc. Some factors for deciding how to archive multimedia items are:

a. Discs can be produced either as replicated (CD-ROM) or recorded (CD-R).
b. Quantity determines the best choice. If the quantity is less than 500, the most cost-effective method is to record the discs. If the quantity is over 500, replication is more cost effective.
c. The type of disc used and its method of manufacture are also important considerations when comparing cost. Some discs are just pennies each, while others may cost $1.00 or more.
d. For archival purposes, a phthalocyanine (photosensitive) dye polymer, a gold or silver alloy metallic reflective layer, and a secondary protective coat of resin are the best combination. With this in mind, a recent search found, for example, the Mitsui Archive CD-R Standard Gold disc at about $1.40 each. Also, Kodak offers the Kodak CD-R Ultima Gold disc that their testing has shown to last over 100 years. This disc has the less desired layer of cyanine dye, but comes with the gold reflective layer. The cost of these discs is about $0.30 each.
e. For short-term storage, CD-RW discs can be erased and rewritten thousands of times without any breakdown in quality.
f. Another factor in the cost and final output on compact discs is the labeling. Screen-printing is the most cost effective method of printing labels in large quantities (over 100) if the label does not include photographs. Inkjet printing is ideal for small production quantity if the disc has a prepared surface that will accept the inkjet print. If not, a CD label made from a template and paper is the easiest and cheapest format for printing labels. If this method is used, the label must be carefully centered on the disc or the laser may not read the CD properly.

2.7 Standards and Compatibility

Industry standards are dictated by four books from Philips and Sony: the Red Book for CD audio, the Yellow Book for CD-ROM and CD-ROM/XA, the Green Book for CD interactive, and the Orange Book for magnetic optical drives, CD-R, and CD-RW. In addition, there are the White Book and the Blue Book, which deal with videodiscs. These standards regulate the production and development of platforms and discs to meet the current and future needs of the user. Very important issues that archivists must deal with include future technology shifts and what platforms will be compatible with today's discs. Current CD-ROM drives are supposed to read data from both CD-ROMs and CD-Rs, and DVD players are backward compatible with existing technologies. However, some problems have arisen, particularly with DVD drives reading CD-R drives. Some theorize that such problems may be due to the dye used in the discs. As technology continues to develop at an ever-increasing pace, archivists will have to continually monitor product developments and their possible impacts on archived material and the ability to retrieve archived data.

CHAPTER 3

THE BLU-RAY DISC (BD)

3.1 Introduction

Unlike DVDs and CDs, which started with read-only formats and later added recordable and re-writable formats, the Blu-ray disc was initially designed in several different formats:

a. BD-ROM (read-only). - for pre-recorded content.
b. BD-R (recordable). - for personal computer (PC) data storage.
c. BD-RW (rewritable). - for PC data storage.
d. BD-RE (rewritable). - for HDTV recording.

The following information pertains mainly to Blu-ray disc recordable (BD-R) media used for recording data files via the PC, and not for copy-protected encoded movies.

Blu-ray is the next generation of optical disc format for high-density data storage and playback of high-definition (HD) movies. The Blu-ray was developed jointly by the Blu-ray Disc Association (BDA), a group of leading consumer electronics, personal computer, and media manufacturers. The group included Apple, Dell, Hitachi, Hewlitt-Packard (HP), JVC, LG, Mitsubishi, Panasonic, Pioneer, Philips, Samsung, Sharp, Sony, TDK and Thomson.

The Blu-ray disc is based on an industry standard format supported by 190 companies and is written in the same ISO standard Universal Disc Format (UDF) as the standard CDs and DVDs. The Blu-ray name is a combination of "blue," for the color of the laser that is used, and "ray," for optical ray. The "e" in "blue" was purposefully left off, according to the manufacturers, because an everyday word cannot be trademarked.

Current optical disc technologies such as DVD, DVD±R, DVD±RW, and DVD-RAM, use a red laser to read and write data, while Blu-ray uses a blue-violet laser (see Figure 3-1). The benefit of using a blue-violet laser (405 nm) is that it has a shorter wavelength than a red laser (650 nm), making it possible to focus the laser spot with greater precision. Therefore, the Blu-ray technology can pack data more tightly, store data in less space, and fit more data on a disc the same size as a CD/DVD.

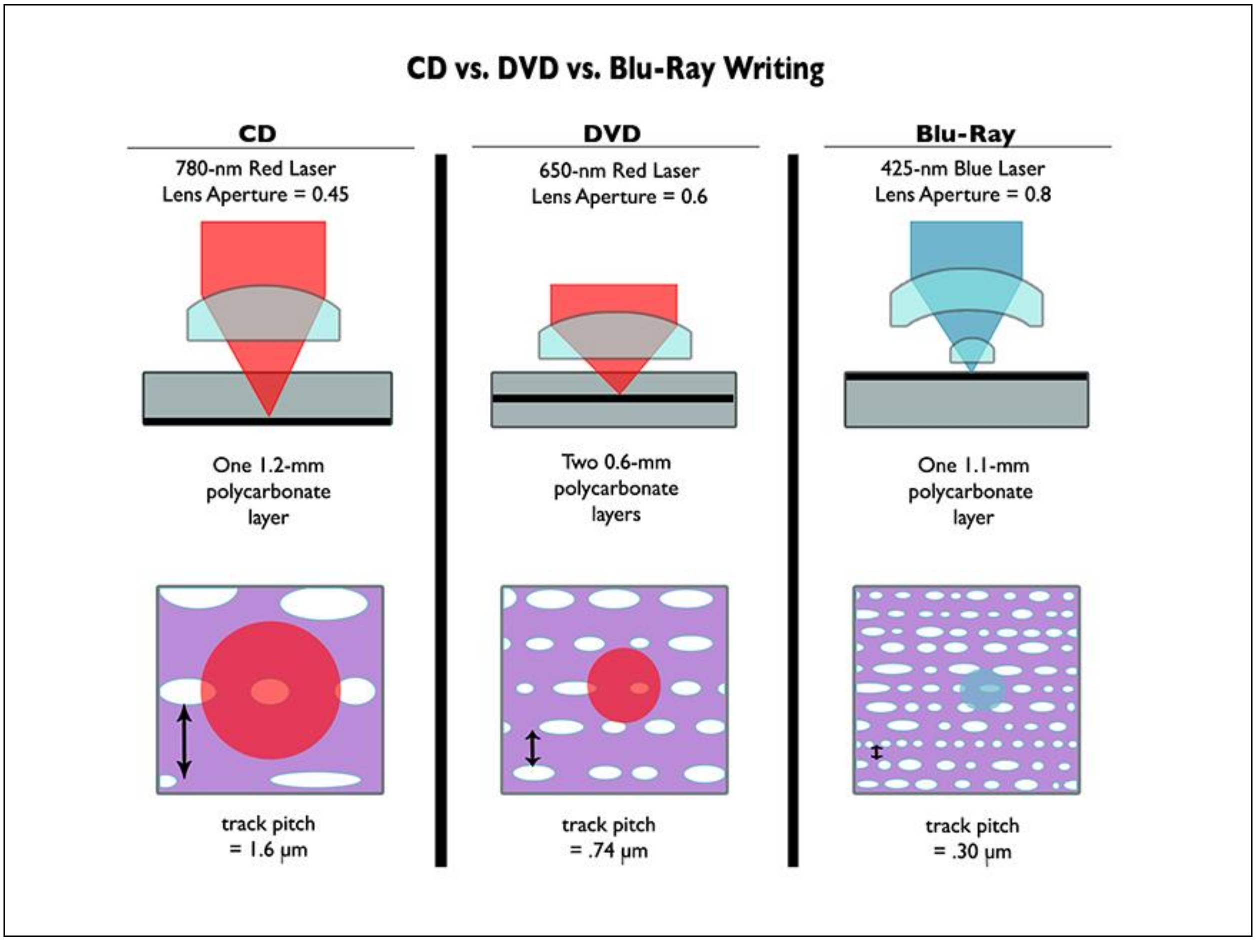


Figure 3-1. CD vs. DVD vs. Blu-ray writing.

3.2 Blu-ray Disc Characteristics

The disc has the same physical form factor as CD and DVD media with current storage capacity of 25GB (single layer) and 50 GB (double layer), as seen in Figure 3-2. Storage capacity roadmaps include increases to 100 GB on 4-layer medium and 200 GB on 8-layer medium.

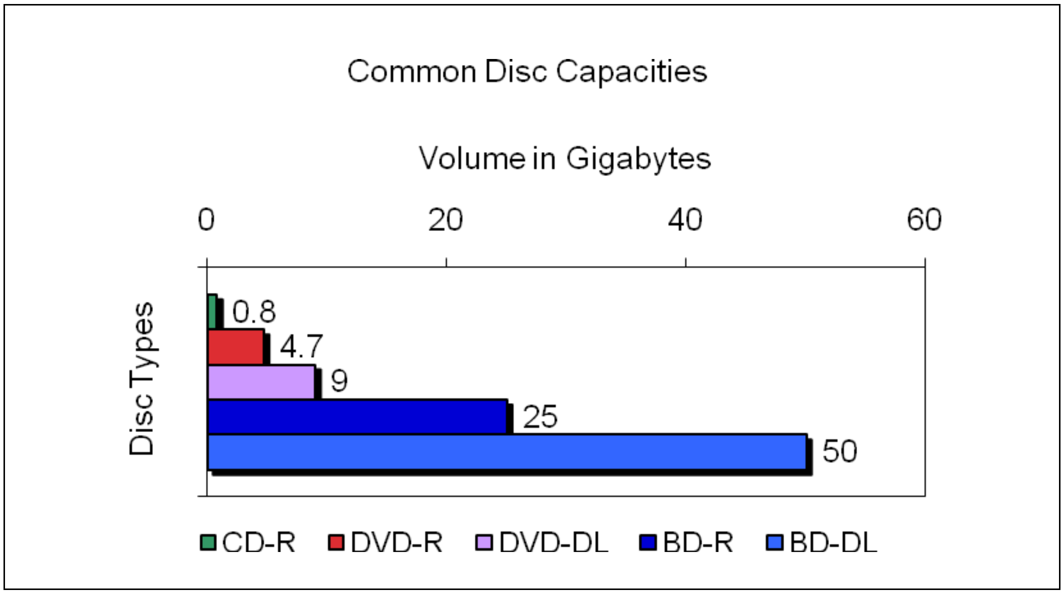


Figure 3-2. Common disc capabilities.

All new PC compatible Blu-ray disc drives on the market today are backward compatible with most DVD and CD formats. A Blu-ray drive that can write BD-R discs can also read and write DVDs and CDs. The fastest commercially available drives today are 8X which translates into a 15 minute write time, not including verification, for a 25 GB data disc (see Table 3-1). At this time, the theoretical maximum write rate for Blu-ray is 12X, which happens about 10,000 RPM, above which there is too much wobble for the disc to read or write accurately. Today, the fastest available media is 6X. In "real world" write tests conducted at Parks Photographic Laboratory at Eglin Air Force Base (AFB), FL, it took 21 minutes and 10 seconds (21:10) to write 23.12 GB on 4X media. High data throughput is achieved by these drives by connecting them to the PC via a Serial Advanced Technology Attachment (SATA) port instead of integrated drive electronics (IDE), as are most CD/DVD burners.

TABLE 3-1. RECORDING SPEED IN MINUTES

Drive speed	Write Time for Blu-ray Disc (Minutes)		
	MB/s	**Single Layer**	**Dual Layer**
1×	4.5	90	180
2×	9	45	90
4×	18	23	45
6×	27	15	30
8×	36	12	23
12×*	54	8	15

* Theoretical

One benefit of the fast SATA connection is the speed at which both large and small files play. When playing large (5-6 GB) files on a DL data DVD, there is a time lag while the disc spins up; then if the file is scrubbed back and forth looking for a specific point, playback will be uneven. In read/write tests, Blu-ray discs responded nearly as well as hard-drives and played files readily.

3.3 Blu-ray Disc Composition

Each Blu-ray disc is about 1.2 millimeters (mm) thick, which is approximately the same thickness as a DVD. But the two types of discs store data differently (see Figure 3-3). In a DVD, the data is sandwiched between two polycarbonate layers, each 0.6 mm thick. Having a polycarbonate layer on top of the data can cause a problem in which the substrate layer refracts the laser light into two separate beams. If the beam is split too widely the disc cannot be read. Also, if the DVD surface is not exactly flat, it will not be exactly perpendicular to the beam, and a problem known as “disc tilt,” in which the laser beam is distorted, can occur.

The Blu-ray disc overcomes DVD-reading issues by placing the data on top of a 1.1 mm thick polycarbonate layer. Having the data on top prevents diffraction and beam splitting from reading through the polycarbonate, thereby preventing readability problems. Additionally, with the recording layer sitting closer to the objective lens of the reading mechanism, the problem of disc tilt is virtually eliminated.

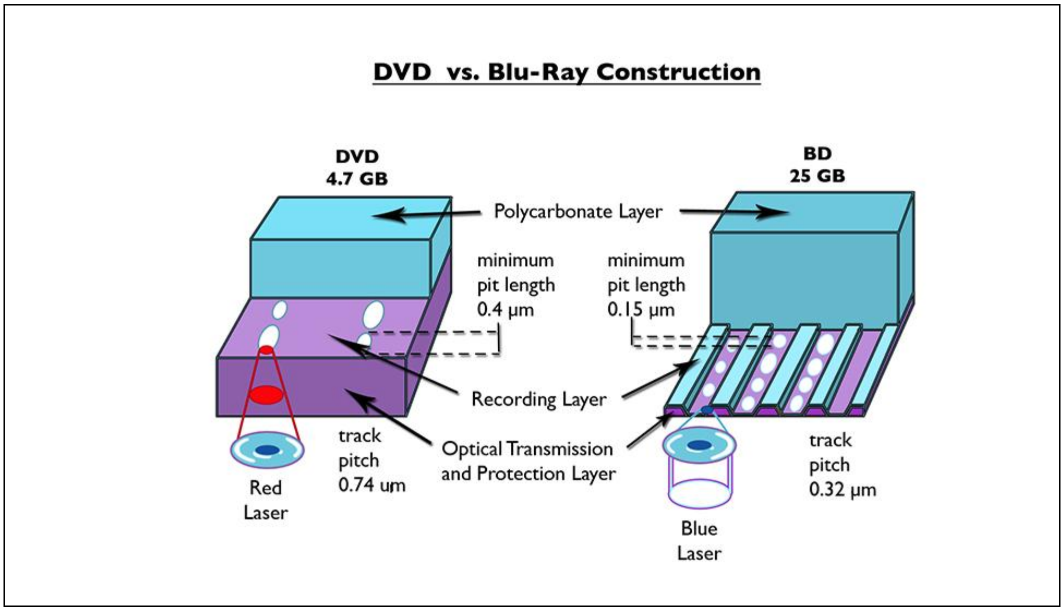


Figure 3-3. DVD versus Blu-ray construction.

3.4 Blu-ray Disc Durability

Because the data is closer to the surface, a hard coating is placed on the outside of the disc to protect it from scratches and fingerprints. The first discs, without this coating, were housed in cartridges for protection. Blu-ray media is liquid repellant and offers greater protection against extreme temperature and humidity than protection provided by CD and DVD media.

The printable BD-R shown at Figure 3-4 was intentionally scratched and fingerprinted to see if read and write capabilities would be degraded. During testing at Eglin AFB, technicians wrote 23.12 GB of data, encountered no errors, and successfully re-played all the files.

Figure 3-4. Intentional scratches on a Blu-ray disc.

3.5 Blu-ray Disc Handling and Storage

A few guidelines for handling and storage of BDs are:

a. Handle a BD by its outer edges, by the center hole, or center-hub clamping area.
b. Avoid flexing or dropping the disc or exposing it to direct sunlight, excessive cold, heat, or humidity.
c. Handle only when being used and do not eat, drink or smoke close by.
d. Discs should be stored in jewel cases or video boxes (rather than sleeves). Since cases do not contact disc surfaces, they provide better protection against dust, debris, scratches, light, and rapid humidity changes.
e. Once discs are placed in their cases, additional protection can be provided by keeping them in a closed box, drawer or cabinet.
f. For long-term storage, it is prudent to follow disc manufacturer instructions as well as the various international standards for preserving optical media.

The vast majority of archived media's time is spent in storage, so the surrounding environmental conditions can have a large effect on the archiving process. Although recommended storage conditions are available from the manufacturer, the recommended conditions are typically between 5° C and 30° C with a non-condensing relative humidity between 8 percent and 50 percent. As storage times increase, the storage temperature and relative humidity should migrate towards the lower end of the recommended spectrum.

Detailed information on storage and handling standards, storage environments, and operating environments are provided in the tables that follow.

Table 3-2. Optical Media Storage and Handling Standards
Table 3-3. BD/DVD/CD Disc Storage Environment
Table 3-4. BD/DVD/CD Disc Operating Environment

TABLE 3-2. OPTICAL MEDIA STORAGE AND HANDLING STANDARDS

Standard	Description
ISO 18925:2008	Imaging Materials – Optical Disc Media – Storage Practices
ISO 18934:2006	Imaging Materials – Multiple Media Archives – Storage Environment
ISO 18938:2008	Imaging Materials – Optical Discs – Care and Handling for Extended Storage

TABLE 3-3.   BD/DVD/CD DISC STORAGE ENVIRONMENT

Condition	**BD-R**	**BD-RE**	**DVD-ROM**	**DVD-R SL**	**DVD+R SL**	**DVD-R DL**	**DVD+R DL**	**DVD-RAM**	**DVD-RW SL**	**DVD+ RW SL**	**CD-ROM**
Specification	BD-R Part 1	BD-RE Part 1	ECMA-267	ECMA-359	ECMA-349	ECMA-382	ECMA-364	ECMA-330	ECMA-338	ECMA-371	ECMA-130
Temperature (˚C)	-10 to 55	-10 to 55	-20 to 50	-20 to 50	-10 to 55	-20 to 50	-10 to 55	-10 to 50	-20 to 50	-10 to 55	-20 to 50
Relative humidity(%)	5 to 90	5 to 90	5 to 90	5 to 90	3 to 90	5 to 90	3 to 90	3 to 85	5 to 90	3 to 90	5 to 90
Absolute humidity (g/m^3)	1 to 30	1 to 30	1 to 30	1 to 30	1 to 30	1 to 30	1 to 30	1 to 30	1 to 30	1 to 30	N]A
Atmospheric pressure (kPa)	60 to 106	60 to 106	75 to 106	75 to 106	60 to 106	75 to 106	60 to 106	75 to 106	75 to 105	60 to 106	75 to 105
Temperature variation (˚C/h)	≤15	≤15	≤15	≤15	≤15	≤15	≤15	≤10	≤15	≤15	N/A
Relative humidity variation (%/h)	≤10	≤10	≤10	≤10	≤10	≤10	≤10	≤10	≤10	≤10	N/A
Wet bulb Temperature (˚C)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	≤29

TABLE 3-4. BD/DVD/CD DISC OPERATING ENVIRONMENT

CONDITION	BD-R	BD-RE	DVD-ROM	DVD-R SL	DVD+R SL	DVD-R DL	DVD+R DL	DVD-RAM	DVD-RW SL	DVD+W SL	CD-ROM
Specification	BD-R Part 1	BD-RE Part 1	ECMA-267	ECMA-359	ECMA-349	ECMA-382	ECMA-364	ECMA-330	ECMA-338	ECMA-371	ECMA-130
Temperature (˚C)	5 to 55	5 to 55	-25 to 70	-25 to 70 (read) -5 to 55 (write)	5 to 55	-25 to 70 (read) -5 to 55 (write)	5 to 55	5 to 60	-25 to 70 (read) -5 to 55 (write)	5 to 55	-25 to 70
Relative humidity (%)	3 to 90	3 to 90	3 to 95	3 to 95 (read) 3 to 95 (write)	3 to 85	3 to 95 (read) 3 to 95 (write)	3 to 85	3 to 85	3 to 95 (read) 3 to 95 (write)	3 to 85	10 to 95
Absolute humidity (g/m^3)	0.5 to 30	0.5 to 30	0.5 to 60	0.5 to 60 (read) 0.5 to 30 (write)	1 to 30	0.5 to 60 (read) 0.5 to 30 (write)	1 to 30	1 to 30	0.5 to 60 (read) 0.5 to 30 (write)	1 to 30	0.5 to 60
Atmospheric pressure (kPa)	60 to 106	60 to 106	N/A	N/A	60 to 106	N/A	60 to 106	N/A	N/A	60 to 106	N/A
Temperature gradient (˚C/h)	N/A	N/A	N/A	≤15 (read)	≤10	≤15 (read)	≤10	≤10	≤15 (read)	≤10	N/A
Relative humidity gradient (%/h)	N/A	N/A	N/A	≤10 (read)	≤10	≤10 (read)	≤10	≤10	≤10 (read)	≤10	N/A
Sudden change of temperature (˚C)	N/A	N/A	≤50	N/A	N/A	N/A	N/A	N/A	N/A	N/A	≤50
Sudden change of relative humidity (%)	N/A	N/A	≤30	N/A	N/A	N/A	N/A	N/A	N/A	N/A	≤30

3.6 Blu-ray Disc Affordability

A Blu-ray disc is more expensive than a DL-DVD-R disc. A search of four Internet sites revealed an average price of $5.50 for a BD-R (2X and 4X, 25 GB) disc. The same Internet sites revealed an average price of $1.45 for a DL-DVD-R (8X, 8.5 GB) disc. Since the BD-R holds 2.94 times more data than the DL-DVD-R, multiplying the cost of the DL-DVD-R disc by 2.94 results in an equivalent size comparison. Therefore, $4.26 is the equivalent cost for 25 GB of data written to DL-DVD-R discs, and the difference is $1.24 per disc. When considering the labor cost to write, catalog, label, and store extra DVD discs, Blu-ray is more economical.

The cost of internal drives to write BD-R discs (and also write DVD and CD media) varies from $180 to $399. The BD-R drives are the same form factor as CD/DVD drives and are a direct replacement, except for the requirement of a SATA port instead of IDE.

3.7 Blu-ray Disc Archive and Longevity

A Blu-ray disc meets legal regulations because it prevents rewriting and tampering with stored data. A finalized BD-R is considered a WORM (Write Once Read Many) type of data storage and it cannot be modified.

A Blu-ray archive consumes no energy when the discs are stored on a shelf. A computer database provides a method of finding specific data on labeled and cataloged discs. Depending on the frequency and speed of access required for an archive, a disc jukebox can be used to access hundreds of discs over a network with much less energy than hard drive arrays. The juke box will also keep the discs organized and protected.

Blu-ray disc manufacturers warranty discs from 50 to 200 years. A new media type may emerge before a disc goes bad, but the long warranty periods show the confidence that Blu-ray manufacturers have in their discs. For example, the Delkin company claims to have the longest archival lifespan (200 years) for their Archival Gold® Blu-ray recordable media.

3.8 Conclusion:

Given the choice of currently available storage technologies, Blu-ray makes a compelling case and should be seriously considered when choosing a technology where permanence and access are key criteria. Considerations should be that Blu-ray media:

a. Is not a single source technology.
b. Has a data archive life greater than 50 years.
c. Has a high access speed.
d. Is highly durable.
e. Is a highly stable media.
f. Constitutes “green” storage technology.

As long as quality media is used from the beginning of the archival process and proven, tested industry standards for handling and storage are implemented; archived data should last until the next new technology is ready to take over.

3.9 References for Chapter 3

a. http://adterrasperaspera.com/blog/2006/10/30/how-to-choose-cddvd-archival-media

b. http://www.delkin.com/pdf/user_guides/archivalgold_whitepaper.pdf

c. http://www.opticaljukeboxes.com/about-blu-ray.htm

d. http://www.opticaljukeboxes.com/PDF/Plasmon/Optical%20Media%20Life%20Prediction.pdf

e. http://www.opticaljukeboxes.com/PDF/UDO%20vs%20Tape%20for%20Archiving%20Data.pdf

f. http://www.channelregister.co.uk/2009/01/16/plasmons_ignominious_end/

g. http://panasonic.net/avc/blu-ray_disc/archive.html

h. http://www.youtube.com/watch?v=HX_Q3bJwGk0

i. http://www.powerfile.com/data-storage-54-116.html

j. http://www.powerfile.com/download/casestudy-sunset.pdf

k. http://www.powerfile.com/download/newlife-wp.pdf

l. http://www.powerfile.com/download/TechBrief_EVAST-03MAR08.pdf

m. http://electronics.howstuffworks.com/blu-ray1.htm

n. http://www.rorke.com/av/archiving-appliance.cfm

o. http://en.wikipedia.org/wiki/Blu-ray_disc

p. http://www.emedialive.com/articles/readarticle.aspx?articleid=11423

q. http://www.supermediastore.com/dvd-plus-r-dual-double-layer-section.html

r. http://www.supermediastore.com/tdk-blu-ray-blue-ray-dvd.html

s. http://www.google.com/products/catalog?hl=en&client=safari&rls=en-us&num=30&newwindow=1&q=blu-ray+media&um=1&ie=UTF-8&cid=4180225026497122055#ps-sellers

t. http://www.daxarchiving.com/en/products/blu-ray-archive/challenge.html

u. http://www.blu-raydisc.com/Assets/Downloadablefile/BD-R_Physical_3rd_edition_0602f1-15268.pdf

CHAPTER 4

SUMMARY

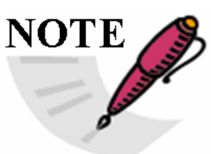
4.1 Archiving: Videotape, Compact Disc (CD) and Digital Versatile Disc (DVD)

The predecessor to this document (RCC document 462-04) evaluated state of the art archiving options for videodiscs, CDs, and DVDs at the time of publication in January 2004. The archiving guidance in the 2004 summary is still valid. However, with the advent of the Blu-ray, it is no longer true that writable DVDs are the latest and most expensive technology. The original document summary is repeated below.

> "Key factors to consider in archiving data include the life expectancy of the media upon which the data is archived and the capability for long-term and backward compatibility for playback and data retrieval. CDs and digital tape are reliable and have become relatively inexpensive. Writable DVDs, which are the latest and most expensive technology, make it possible to enjoy enhanced video, audio and increased data storage. In storing still and video files, one has a choice of storing in either the native formats or as compressed files. In a few years we may have high-density DVDs, with hundreds of gigabytes of storage. There may be no permanent, ultimate archival media. The choice of archival media depends on your preferences and options at the time you make your decision and, of course, the amount of available funding."

4.2 Newer Technology: The Blu-ray Disc.

In February, 2010, the Blu-ray technology was added to this document as Chapter 3. The new Blu-ray technology boasts longer archive life as well as more storage space compared to other discs. Specific considerations for using Blu-ray are at paragraph 3.8.



It is anticipated that this document, particularly the conclusions, will be radically rewritten as new storage technology is developed and becomes available.

This page intentionally left blank.

CHAPTER 5

REFERENCES

5a. Adams Magnetic Products, Inc. (2001). Longevity of the Recorded Information, Adams, B. [CD-ROM]. Retrieved April 9, 2002 from the World Wide Web: http://www.ampcass.com/about.html

5b. Baltmedia. (1997-2002). Technologies. Retrieved 2002, April 9, 2002 from the World Wide Web: http://www.multimedia.lv/techno/contmr.htm

5c. The CD Information Center (Cochrane, K.). (2002). CD Futures. Retrieved 09 April 2002 from the World Wide Web: http://www.cd-info.com/CDIC/History/futures.html

5d. The CD Information Center (Cochrane, K.). (2002). Recordable CD and DVD for Archiving. Retrieved 09 April 2002 from the World Wide Web: http://www.cd-info.com/CDIC/Applications/Archiving.html

5e. Compugraf. (2002). Communication on Digital Media. Retrieved 10 October 2002 from the World Wide Web: http://www.compugraf.be/tactical06_fr.htm

5f. Disctronics. (2002). "DVD Disc Layout & Formats" Making CDs & DVDs at Disctronics. Retrieved 10 October 2002 from the World Wide Web: http://www.disctronics.co.uk/ technology/dvdintro/dvd_formats.htm

5g. Fujifilm. (2002). "DVD-RW." Fujifilm Media Source. Retrieved 10 October 2002 from the World Wide Web: http://www.fujifilmmediasource.com/dvdspec.asp?type=dvdrw%2D

5h. Hinton, H. (2002). "How Discs are Damaged." Compact Disc Repairman, Inc. Retrieved 09 April 2002 from the World Wide Web: http://www.cdrepairman.com/how_disc_damaged.shtml

5i. Kodak. (1993, October 18). "Shelf Lives and Videotape." Fortune Magazine article, Retrieved 16 September 2002 from the World Wide Web: http://kodak.com/country/US/en/motion/ support/technical/shelf.shtml

5j. Kodak. (2001, October). Storing Kodak CD-R Media. Technical Information Bulletin Tib 4300, Kodak, 2001.

5k. Kopy Rite. "CD Duplication: Overview and Comparisons." Kopy Rite Electronic Data Duplication. Retrieved 09 April 2002 from the World Wide Web: http://kopyrite.com/optical.html

5l. Murphy, W. T. (1997). Television and Video Preservation Study: Volume 1 Report. Library of Congress. Retrieved 15 September 2002 from the World Wide Web: http://lcweb.loc.gov/film/tvstudy.html

5m. Philips. "DVD+ReWritable and How It Works." Philips Consumer Electronics Press Room. 10 October 2002 http://www.press.ce.philips.com/pers/uploads/attachment/backgrounder_on_dvd+rewritable.pdf

5n. Pioneer. "DVD Technical Guide" Sound.vidsion.soul. Retrieved10 October 2002 from the World Wide Web: http://www.pioneer.co.jp/crdl/tech/dvd/2-e.html

5o. Stinson, D., Armeli, F., Zaino, N. "Lifetime of KODAK Writable CD and Photo CD Media.". The CD Information Center. Retrieved 09 April 2002 from the World Wide Web: http:// www.cd-info.com/CDIC/Technology/CD-R/Media/Kodak.html

5p. Toshiba. "What's DVD? Chapter 4: DVD's 3 application formats and 3 recording types." Retrieved 09 April 2002 from the World Wide Web: http://www.toshiba.co.jp/dvd/e/whats/wh04/w040lidx.htm

5q. Wheeler, J. Videotape Preservation Fact Sheets. Stanford University. The Association of Moving Image Archivists, 2002. Retrieved 15 September 2002 from the World Wide Web: http://www.stanford.edu/~hfrost/video/intro.html

5r. Whitaker, J. (2001). DTV Handbook, The Revolution in Digital Video. (3rd ed). McGraw-Hill.